Addition of A WOOD-FIRED BOILER at the UNIVERSITY of NEW BRUNSWICK Fredericton, NB

ADI LIMITED
1984

54

CANADA/NEW BRUNSWICK CREDA PROJECT NUMBER 2047

ADI Limited
Engineers, Architects, Planners,
Management Consultants, Surveyors

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Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

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This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

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EXECUTIVE SUMMARY

A wood-fired boiler was added to the central heating plant of the University of New Brunswick in Fredericton, N. B. and began operation in March, 1984. The plant was designed and built under a design/procure/construct contract by Northeast Energy Services Limited of Fredericton, N. B. at a total cost, including interest during construction, of $2 420 000. ADI Limited was retained by Northeast to provide engineering services.

Northeast had applied for financial assistance under the Conservation and Renewable Energy Demonstration Agreement (CREDA) which is jointly funded by the Government of Canada and the Province of New Brunswick (Energy Secretariat) and a committment of $500 000 toward the construction cost of the plant was received. This grant would reduce the University's capital outlay for the project to $1 920 000. An additional $35 000 was contributed by CREDA to cover performance monitoring and information transfer costs. ADI Limited was retained by Northeast to provide engineering services. The boiler has a capacity of 40 000 pounds of steam per hour at 250 psig when firing wood fuel with a moisture content of 50 percent (wet basis).

The wood fuel for the boiler is a mixture of bark, sawdust and shavings which is collected from four sawmills within a 60 kilometer radius of Fredericton and then hogged and screened at a local mill site before delivery to the heating plant.

During the 6-month period ending September 30, 1984, the wood-fired boiler produced 90.9 million pounds of steam which is equivalent to 71.4 percent of the central plant's

total steam output for the period. The average moisture content of the wood fuel for the period was 50.4 percent and the average boiler efficiency (input-output basis) was 68.2 percent.

The net saving to the University for the 6-month monitoring period, after all direct operating costs but before interest, and principal payments on borrowed capital, was $278 000 and this is a good indication that the annual figure of $600 000 will be met or exceeded.

SOMMAIRE EXECUTIF

Une chaudière alimentée au bois a été ajoutée au système de chauffage central de l'Université du Nouveau-Brunswick à Fredericton (N.-B.) et fonctionne maintenant depuis mars 1984. L'installation a été conçue et mise en place en vertu d'un contrat de conception/approvisionnement/construction conclu avec Northeast Energy Services Limited de Fredericton (N.-B.) à un coût total de 2 420 000 $, y compris les intérêts pendant la construction. Le sous-traitant choisi par Northeast pour les services techniques était ADI Limited.

Northeast avait présenté une demande d'aide financière en vertu de l'Accord de démonstration des économies d'énergie et des énergies renouvelables (A.D.E.E.E.R.) financé conjointement par le Gouvernement du Canada et la Province du Nouveau-Brunswick (Secrétariat à l'énergie), et a reçu un engagement de 500 000 $ visant le coût de construction de l'installation. Cette subvention a réduit l'investissement en capital de l'université à 1 920 000 $ pour l'ensemble du projet. Une somme additionnelle de 35 000 $ était versée en vertu de l'A.D.E.E.E.R. pour couvrir les frais de monitorage du rendement et de transfert de l'information. La firme choisis par Northeast pour dispenser ces services techniques est ADI Limited. La chaudière a une capacité de 40 000 livres de vapeur à l'heure à 250 lb/po2 lorsqu'elle est alimentée avec du bois dont la teneur en humidité est de 50 p. 100 (poids humide).

Le bois servant à alimenter la chaudière est un mélange d'écorce, de sciure et de copeaux de bois, provenant de quatre scieries dans un rayon de 60 kilomètres de Fredericton, qui est déchiqueté et soumis à une procédure de triage dans une scierie locale avant d'être livré à l'installation de chauffage.

Pendant la période de 6 mois qui s'est terminée le 30 septembre 1984, la chaudière au bois a produit 90,9 millions de livres de vapeur, soit l'équivalent de 71,4 pour 100 du rendement total de l'installation centrale durant cette période. La teneur en humidité moyenne du bois pour cette période était de 50,4 pour 100 et l'efficacité moyenne de la chaudière (consommation-rendement) a été de 68,2 pour 100.

L'économie nette pour l'université pendant la période de monitorage de 6 mois, une fois calculés tous les coûts directs de fonctionnement mais avant le paiement du principal et des intérêts sur le capital emprunté, a été de 278 000 $, ce qui est une bonne indication que le chiffre annuel de 600 000 $ sera atteint ou même dépassé.

1.0 INTRODUCTION

1.1 General

In September 1982, Northeast Energy Services Limited made a preliminary proposal to the University of New Brunswick for the addition of a 40 000 pph wood-fired boiler to the University's central heating plant. The proposal provided for the design and installation of the complete facility along with responsibility for long-term financing, wood fuel supply, training of the plant operators, supervision of plant start-up and continuing technical assistance for operation and maintenance of the plant.

The estimated total construction cost including engineering design, start-up, interest during construction, and provision of spare parts was $2 400 000.

During the years 1980 to 1982 the plant had produced between 330 million and 350 million pounds of steam annually and had consumed between 2.2 million and 2.5 million imperial gallons of Bunker "C" (No. 6) fuel oil.

It was estimated that the new wood boiler, operating as a base load energy supplier, could produce 240 million pounds of steam per year which would be roughly equivalent to 70 percent of the plant's total production requirements.

Annual net fuel savings for the project after allowing for wood fuel, extra operating and maintenance costs and technical assistance were estimated to be $600 000 per annum at current fuel oil prices.

In February 1983, officials of the University and Northeast Energy signed the formal agreement to proceed with the project and detailed design and procurement activities began immediately.

1.2 Existing Plant

The U.N.B. heating plant has utilized two (2) oil-fired boilers to supply the heating and domestic hot water needs for the campus, the Dr. Everett Chalmers Hospital (DECH) and two apartment buildings operated by the University. The two boilers were installed in 1970 and are of the Foster Wheeler type AG-5120 Monowall Design, each with one Peabody Model Mt 33 burner firing number 6 (Bunker C) oil, and have a rated maximum capacity of 120 000 pounds of steam per hour at 250 psig (nominal). The plant has operated at a relatively high load factor as a result of the hospital demand.

The heat energy from the plant is distributed via an underground pipeline system with steam feeds to and condensate returns from all major buildings on the campus (UNB and St. Thomas), the DECH, a garage currently in use by the Department of Highways and the off campus apartments. The condensate return rate is in the order of 90 to 95%.

The annual steam production for the plant varies from a low of 330×10^6 pounds of steam to an estimated high of 350×10^6 pounds. The load rarely exceeds 100 000 pounds per hour (pph) in winter and is seldom less than 15 000 pph during the summer. Load variations are relatively slow, such as would be expected from a predominantly heating load. However, on occasion, particularly during the summer months, the air conditioning load at the Hospital can create an additional 20 000 to 25 000 pph of steam demand within minutes.

The water for use in the plant is taken from the city mains, passed through a water softening system and mixed with the returned condensate. The mixed condensate and raw water make-up is fed into a Graver Deaerator where the temperature is maintained at 265°F by direct contact with steam at 25 psig.

The heater water is then transferred to the boilers by means of two steam turbine driven pumps and/or an electric motor driven pump.

The steam is generated at 250 psig and distributed from the plant header to the University and the Hospital where it is reduced to its working pressure. The plant steam distribution system has three operating pressure levels; 250, 125 and 30 psig. The steam driven turbines use 250 psig steam, oil heaters require 125 psig steam and the deaerator uses 30 psig steam. Pressure reducing stations provide the necessary header control within the plant.

The plant's electrical needs are supplied by the New Brunswick Electric Power Commission power grid. A stand-by diesel generator is located at the plant in the event of a power failure. The generator has been sized to enable the plant to operate one boiler to provide continuity of steam supply, especially for a critical user such as the Hospital.

The existing boilers at the plant operate on Bunker C Oil. This is delivered to the plant by tractor trailer units and stored in the 230 000 gallon storage tank located directly behind the plant. Prior to firing in the boilers, the oil is passed through a Duplex Steam Heating/Pump set to raise the pressure and temperature of the oil to 225 psig and 220°F. The boilers use steam atomization at the burner for combustion enhancement. The plant's oil consumption has ranged from 2.2 to 2.5 million gallons per year.

Provisions were made during the initial design of the existing plant for the installation of a third oil fired boiler. Floor space was made available and all auxiliary streams such as oil, feedwater, compressed air and electrical power were sized to easily accommodate an additional unit.

2.0 TECHNICAL DESCRIPTION

2.1 General Features

In early 1983, ADI Limited completed an energy study for the University of New Brunswick on its Central Heating Plant. The results of this study indicated that substantial energy savings could be realized by the addition of a wood-fired boiler at the plant. The boiler size recommended was a 40 000 pph unit which would handle the complete plant load during the warmer summer months and carry 60% of the steam requirements during the winter heating season.

The Northeast Energy Services design concept for this additional unit was to maintain the structural and architectural integrity of the existing plant with the addition of the new boiler and auxiliary equipment. Figure 1, Appendix 1 in this report illustrates the final perspective of the plant upon completion of the project.

The general plant design required the procurement of wood unloading and storage facilities to be located at the Central Heating Plant. A system was installed which could efficiently unload any type of wood truck delivering to the plant, from dump trucks carrying 12 tons to the large self-unloading tractor trailer units capable of delivering 25 tons per load. The wood storage system installed at the plant was sized and designed to hold two full days storage for the boiler, thus allowing for weekend operation and providing a surge capacity at the plant in the event of problems in wood supply.

In designing for maximum load conditions on the wood-fired boiler, a wood feed system, capable of transferring 10 tons/hour of wood residue to the boiler, was installed. The wood feed system draws wood automatically from one of the two storage

silos to the boiler by a series of conveyors within the plant. Figure 2, Appendix 1 illustrates the general wood handling arrangement by cut-away perspective. The boiler operates automatically and the instrumentation is a pneumatic type supplied by Bailey Controls. The boiler controls monitor header pressure, wood feed rate, boiler water, steam flow, drum level, total air flow and distribution and boiler drafts. All parameters are automatically controlled to a desired set point value.

The end products of the process of combustion are hot combustion gases and ash. The hot gases in turn heat the feedwater and produce steam. They are then exhausted to atmosphere through the existing stack. Prior to being exhausted to atmosphere the flue gases are passed through an air heater unit to preheat the incoming combustion air. They then enter a dust collector to remove particulate matter from the gas stream to minimize the plant's environmental impact. The ashes collected within the plant are conveyed to outside storage for transferral to landfill site for disposal. A process flow schematic of the general plant process is presented in Figure 3.

2.2 Wood Fuel Receiving

The wood fuel receiving section of this plant was designed to weigh the wood fuel deliveries as they arrive at the plant, unload the trucks and transfer the wood residue to the storage silos inside the plant. The system was designed to enable the delivery and unloading of large self unloading tractor trailer trucks or smaller tandem and dump vehicles. The wood supply contract was based on delivered tonnage of wood residue to the plant. To accurately determine delivered tonnage

a 70 ft by 10 ft, pitless weigh scale was installed at the site. The scale was manufactured by Aurora Scales Ltd. of Aurora, Ontario. The driver backs his load on the deck and a ticket printer identifies gross weight of the vehicle; after unloading the tare weight is recorded and total wood delivery is calculated from this information. The scales are registered with the Department of Weights and Measures for commercial trade transactions. The scale has a capacity of 80 tons and utilizes 6 load cells as weight sensors.

After recording the vehicle's gross weight, it is backed up to the wood receiving hopper. The plant operator starts all wood receiving systems from a control panel located inside the plant. The truck dumps its load of wood residue into the 12 ft x 14 ft x 6 ft receiving hopper. This hopper is equipped with a full scraper bottom which discharges into a screw conveyor located in the bottom center of the hopper. The bottom scrapers operate from a hydraulic system complete with cylinders, pump, reservoir, control panel and piping as required for the reciprocating action of the scrapers. The wood residue is moved towards the center of the hopper by the forward movement of the vertical face scraper section. The wood drops into the receiving hopper screw at the center of the bin and is conveyed to the bucket elevator. The transfer of wood from the wood receiving bin to the top of the wood storage silos is accomplished by using this bucket elevator. This unit is a vertical belt conveyor with a series of 16 inch x 8 inch buckets which lift the wood residue a total of 60 feet above the discharge of the wood receiving bin to the silos. The wood discharges from the bucket elevator by centrifugal force at the top roller section thence into a pant leg chute. The operator can direct which silo is to be filled by moving a gate inside this chute. The wood is then moved by one of two silo fill conveyors directly into the center of the silo selected for filling.

The wood receiving system was designed and sized to transfer wood residue from the truck receiving hopper to the storage silos at a rate of 50 tons per hour. Reference Figure 4 for details of the wood flow system.

2.3 Wood Fuel Storage

The wood fuel storage silos were designed to provide a surge or buffer capacity between the wood boiler usage and wood supplier deliveries. Each of the two silos has an inside diameter of 30 feet and an effective height of 40 feet. The walls and floors are of concrete construction designed to withstand the forces imposed by the wood fuel. The silos were designed and constructed by Wilhelm Concrete Ltd. and have an estimated storage capacity of 150 tons of wood per silo.

Space is provided under each silo for the withdrawal of wood. A chain flail type agitator rises from the bottom centre of each silo. The wood fuel is discharged from the silos into a metering bin located immediately below the center opening. The wood is conveyed to the boiler on a demand basis.

2.4 Wood Fuel Handling

The wood fuel handling system incorporates all material conveyors essential for the movement of wood fuel from the silos to the boiler stoker screw. The fuel is obtained from one of the silos as described in Section 2.3. The chain flail system for withdrawal of fuel from the silo is operated automatically to maintain the metering bin under the silos at a set level.

The metering bin has a depth indicator to start the chain flail units when the bins reach a low level. Sensors shut off the flails at high levels thus keeping the discharge screws from the bins completely flooded at all times. The metering bin discharge screws are driven by D.C. variable speed motors. The speed of the motor is automatically adjusted to maintain sufficient wood flow to the boiler to match the steam demand. When the load demand increases, the steam distribution system pressure will drop which sends a signal to the variable speed screws to increase wood feed, which in turn increases the steam output and thus controls the steam pressure at the desired set point of 250 psig. The wood residue discharges from the variable speed screws under the metering bins into a totally enclosed drag chain conveyor. The chain has a series of metal flights welded to the links and conveys the wood from the storage area into the steam plant. A photo eye on the discharge end of this conveyor senses and activates an alarm when the wood feed has stopped, enabling the operator to switch silos and maintain constant wood feed to the boiler. From the drag chain the wood is conveyed to the boiler by a belt conveyor. This conveyor discharges directly into the boiler stoker screw. The entire wood fuel handling sysem is designed to convey a maximum of 10 tons of wood per hour to the boiler.

2.5 Boiler and Auxiliaries

The boiler and all auxiliary equipment were procured from Babcock and Wilcox Canada Ltd. The boiler is of the Towerpak Design and rated for 40 000 pounds per hour of saturated steam at 250 psig. Wood feed to the furnace is accomplished by one underfloor wood screw feeder with a center floor discharge and retort. The screw feeder is a 14-inch diameter screw manufactured by Sullivan Strong Scott. The screw flights are

tapered to feed bark along the shaft. At the furnace retort area the flights are interchanged with kickplates which direct the wood to the furnace floor. The boiler furnace floor has a stationary pin hole grate which allows underfire air passage up through the grates for cooling and combustion air supply for the wood. The towerpak boiler has three combustion air plenums for regulation of air flow into the furnace. The combustion air is taken from inside the plant by means of a forced draft fan and is preheated in a tubular air heater before going to the boiler. The combustion air is preheated to a temperature of 420°F in the air heater. This preheated air is directed into the furnace via the low pressure underfire air plenum, low pressure overfire air plenum or through a high pressure fan into the high pressure overfire air duct. The quantity of air flow into each section of the furnace is controlled automatically by pneumatic damper drives to vary the air flow distribution pattern. The low pressure underfire air is directed under the pin hole grates to provide central air around the retort area or peripheral air for the furnace floor. The undergrate air accomplishes the initial drying of the wood fuel and provides primary combustion air. The low pressure overfire air ducts run along the left and right side of the boiler and enter the furnace at a height of 2 feet above the grate surface. This is a secondary air supply to complete the combustion process.

The high pressure overfire air enters above the low pressure duct at a height of four feet above the furnace floor. This air provides a turbulent zone and acts as a cushion over the fire to ensure complete combustion of the wood fuel and to minimize the carryover of unburnt wood with the gas stream.

The combustion gases leave the furnace area and pass through the generating bank which transfers convective heat for steam generation. The gases exit the boiler at a temperature of 600°F. The flue gas waste heat is recovered in a tubular air heater before entering the dust collector unit. The dust collector is a mechanical multi-cyclone collector manufactured by Air Correction, U.O.P. Inc. The centrifugal action of the gas passing through the collector tubes separates the solid particles such as dust and ash from the gas streams. The cleaner gases leaving the collector enter the inlet of the induced draft fan, which controls the furnace pressure automatically to the desired set point. The combustion gases are directed into the existing plant stack for discharge to the atmosphere.

2.6 Boiler Controls

The complete boiler combustion control system installed for the wood-fired boiler plant was procured from Bailey Controls. Relevant controllers and recorders for the plant are housed on a new panel located inside the existing control room. The controllers installed at the plant were designed to allow for manual or completely automatic operation of the boiler. On the boiler and ancillary equipment, the following process parameters are continuously monitored and indicated on the control panel:

steam flow
water flow
drum level
wood feed
flue gas temperatures at Boiler outlet, and
air heater outlet

combustion P/R temperature
total air flow
furnace and gas train draft levels
air flow distribution pressure levels
flue gas opacity
flue gas oxygen

The major process control loops of the boiler focus on drum level, plant master and air flow control.

The drum level controller on the boiler is of the three element type utilizing actual steam flow, water flow and drum level signals for control activation of the feedwater flow to the boiler.

The plant master enables the wood boiler to respond to changes on steam demand placed on the plant and to match the required wood feed rate to this demand. The control is accomplished by monitoring the plant steam pressure and controlling to the desired header pressure set point of 250 psi. When the header pressure decreases, this represents an increase on steam demand and the plant master automatically increases the wood feed rate to compensate for this demand. To illustrate the effectiveness of the control refer to Figure 5, showing the plant steam pressure recording for July 24, 1984 and the variance from set point of 250 psig experienced at the plant. Figure 6 shows the changes on steaming rate during the same period on the wood fired boiler required to obtain this level of pressure control. The air flow controller is directly related to wood feed rate, which adjusts the undergrate and overfire air flows in direct relation with the wood feed rate changes. The boiler is also equipped with complete safeguards to protect the unit against low water level and over-pressurizing conditions.

2.7 Ash Handling

Inherent with the operation of any wood-fired boiler is the generation of and subsequent disposal of ash. Ash is considered the inert material in wood which is incapable of combustion. However, included with inert materials are quantities of unburnt wood or char collected in the gas passes and sand or rocks which are usual contaminants found in the wood supply. The towerpak boiler installed at the U.N.B. Heating Plant has four distinct areas for the collection and removal of ash; the furnace grate, generating bank hoppers, air heater hopper and the dust collector unit.

Wood fuel contaminants such as sand and rocks will accumulate over time on the furnace grate. Periodically the plant operators will stop wood feeding and manually rake the furnace grate to remove this material from the boiler. The ash and clinkers (sand & rocks) are raked into a hopper located at the front of the boiler, then conveyed to outside disposal bins for removal to landfill.

The remainder of the flyash collected in the boiler is unburnt wood referred to as char or inert wood ash which drops out of the gas stream prior to reaching the stack. As the combustion gases leave the furnace area, they pass through the generating bank section. A drastic change in flow direction at the bottom of the generating bank makes this a natural drop out point for char and ash. The boiler is designed with hoppers and rotary valves at this location to remove this ash accumulation. The rotary valves discharge this material into the ash screw conveyors for transport to the disposal bins. Following the gas stream, the gases pass into a two-pass tubular air heater, which is equipped with a similar hopper and rotary valve for removal of ash. The finer particles of ash are removed from the gas stream in the multi- cyclone dust collector.

All ash collection points are interconnected through a series of four screw conveyors which discharge the ash into one of two (1200 cubic foot) totally enclosed bins. Ash disposal from the air heater and dust collector sections of the boiler is continuous whereas the furnace grate and generating bank discharges are intermittent. To enable continuous plant operation, two bins are provided to allow the disposal contractor to take one bin to the landfill site while the plant utilizes the other.

3. 0 PLANT CONSTRUCTION

3.1 Project Management

Northeast's mandate on this project was to prepare a design, procure equipment, call for bids, oversee the construction and equipment erection and successfully commission the facilities for production of 40 000 pounds of steam per hour. The plant and equipment were to be compatible with the existing plant in quality, process control, and aethestics and conform environmentally to regulations applicable to biomass fired boilers. The works were to be completed within a schedule with costs not to exceed the projected estimate.

As stated elsewhere in this report the schedule and budget were both met and it is forecast that in its first full year of operation the plant performance will equal or possibly exceed earlier expectations.

In order to achieve the desired results, a close liaison was maintained with the administrative and technical staff of the University.

The following describes briefly the major project works and the manner in which each was handled.

The conceptual and detailed designs were performed with a good understanding of the present plant and conflicts with in-place facilities were minimized. The design concept was frequently reviewed with the plant technical staff to maintain comformity with existing processes and systems. Preparation of specifications, bid invitations and contractor selection were based on the quality of previous work or product as well as the cost and capability to complete the undertaking within the budget and schedule.

The inspection of construction was performed on a continuing basis as works progressed. Deficiencies were noted and brought to the contractors' attention for correction.

The operating and maintenance manuals were prepared for operator guidance and for use during installation and commissioning.

The plant staff selected five persons to serve as assistant operators on the new equipment. A training manual was prepared and a training program conducted for the new staff and on an abbreviated scale for the present plant staff.

The plant commissioning was coordinated with equipment suppliers as deemed necessary.

The cost control was maintained through monthly reconciliations which kept management fully aware of committed and projected costs.

The scheduling of activities was very important to prevent duplication of work and to insure that minimum extra costs were required for winter construction and project delays which add to the cost of related works. Strict adherence to prepared schedules was maintained through meetings with the design staff, contractors and commissioning staff.

A monthly report of all major works and activities was instrumental in providing an early awareness of deficiencies or delays.

3.2 Schedule

A bar chart presented in Figure 7 of this report summarizes the engineering and construction schedule for this project. The overall project schedule was maintained as initially projected in the engineering proposal with the plant start-up occurring within one year of the initial agreement being signed. The wood-fired boiler was considered to be in commercial operation on April 1, 1984, representing the initiation of the six month monitoring period at the plant.

4.0 OPERATING EXPERIENCE

4.1 Wood Fuel Supply

The wood residue for the central heating plant is supplied by Northeast Energy Services Limited. The subcontract for wood delivery has been established with Devon Lumber Co. Ltd, a local sawmill company operating within 1.5 miles of the plant. Devon Lumber relies on the production of wood residue from four local sawmills within a 40 mile radius of the plant to maintain a sufficient stock pile and supply the University heating plant with wood residue on an as needed basis.

Throughout the six-month monitoring period, considerable emphasis was placed on quality control of the wood residue, which has a major impact on efficient plant operation. The key quality factors receiving priority were wood sizing, moisture content and blend. Initially all wood residue processed at the Devon Lumber Mill was passed through a hog/cutter unit. This proved ineffective in assuring proper fuel size distribution. Since then, Devon Lumber has installed a Rader Disc screen and chipper for processing of all wood residue. This change has reduced the quantity of oversized wood being delivered to the plant which has resulted in more reliable operation of the wood handling system.

Moisture content of the fuel is probably the single most important quality control parameter with regards to efficient boiler operation. Figure 8 illustrates average wood moistures on a monthly basis. Increased awareness and feedback to the wood supplier has resulted in dramatic reduction in wood fuel moisture levels as wet wood is now mixed with dryer material or left in storage to dry before being delivered to the heating plant.

Table 1 outlines the distribution of measured moisture contents for wood fuel deliveries which produced the average monthly figures.

TABLE 1
MOISTURE CONTENT DISTRIBUTION
for
WOOD FUEL DELIVERIES

	Moisture Content					
MONTH	less than 35%	35-45%	45-55%	55-60%	Over 60%	TOTAL %
April	0	5	20	29	46	100
May	0	3	37	31	29	100
June	0	9	71	17	3	100
July	6	27	64	2	1	100
August	6	76	16	1	1	100
September	0	2	74	23	1	100

The wood residue supplied to the plant is typically a mixture of bark, sawdust, shavings and chips. Varying any one of these constituents affects the overall performance of the plant. Bark has the highest BTU content; however it is usually wetter than the other materials and contains a higher percentage of sand and rocks. The sawdust and shavings are usually dryer but have a lower BTU output. A satisfactory blend of 30-40% bark and 60-70% sawdust and shavings has proven successful for this plant. The sawdust and shavings allow the fuel handling equipment to operate without difficulties, whereas pure bark tends to cause blockages. Samples of wood residue were tested for calorific value and the average heat of combustion for the wood fuel was 8330 BTU/bone dry pound.

Table 2 provides information on the wood fuel deliveries by month and expressed on both "wet" and "bone dry" bases.

TABLE 2
WOOD FUEL DELIVERIES
("wet" and "bone dry" bases)

	Quantity Delivered (wet pounds)	Equivalent Quantity (bone dry pounds)
April	7 170 903	3 011 779
May	6 556 870	2 970 262
June	5 251 586	2 568 025
July	4 664 430	2 556 108
August	2 932 800	1 727 419
September	4 644 030	2 656 385

The wood supplier has recently installed a concrete base pad for wood storage. This has resulted in reduced rock and sand carryover with the wood which improves the furnace operation. To remove tramp metal from the wood supply a permanent magnet has been installed on the wood conveyor system at the plant. Experience to date shows that good quality wood results in good boiler plant operation.

4.2 Wood Fuel Handling

Operating experience throughout the monitoring period has indicated that wood fuel handling equipment reliability is directly related to wood fuel quality; in specific terms,

wood moisture content, sizing and bark content of the wood refuse. The wood unloading system from the receiving hopper to the top of the silo area has operated satisfactorily over the initial monitoring period. The system has a proven capacity of 50 wet tons per hour. Operational difficulties were experienced with oversized wood jamming the screw conveyors or excessive quantities of stringy bark resulting in the wood hanging up in the receiving hopper or causing blockages in the screw conveyor. Improvements in the wood supply and increasing the receiving screw sheave diameters to effect greater torque transmission to the shaft has virtually eliminated operational difficulties in this area.

The wood storage silos have operated well with the exception of plugs resulting from wet fuel being stored in the silo. Future plans are presently under consideration to install high level detectors in each silo which would enable the operators to utilize more fully the available space inside the silos. The system would shut off the wood receiving conveyors automatically when the silos were completely filled and would eliminate the need for the operator to monitor the silo levels constantly when filling. Equipment has also been procured to automatically close the silo discharge gates when the chain flail unit is shut off. Presently the gates are open continuously and when a silo is being filled, wood residue tends to flow out the discharge gate into the metering bin below. This can result in wood compacting around the chain flail units inside the silos. A standard operating procedure has been affected at the plant whereby wood feed into a silo is matched with the silo from which wood is being extracted to the boiler. This reduces the risk of wood residue compacting around the chain flail inside the silo during filling and reduces blockages in this area.

The wood feed conveyor from the storage silos to the boiler have proved problematic with wet or stringy wood. To improve the operation, several changes have been completed. Level indicators in the metering bins under the silo have been modified to reduce the incidence of bridging. This has reduced bin plugging which in turn results in improved wood flow reliability. The DC variable speed drives also required some modifications and have since worked very satisfactorily.

The major improvements realized in the wood handling system have resulted from better control of wood quality and the above mentioned improvement projects planned for this area should increase the system reliability.

4.3 Boiler

4.3.1 Boiler Operation and Performance

The boiler unit has, over the six month monitoring period, met all performance expectations and has proven its capability of delivering its full rated steaming capacity of 40 000 pph. The monitoring program developed for the plant was aimed at evaluating the boiler's performance on a monthly basis and recording the boiler's steam generation, wood consumption and efficiency levels.

The importance of moisture content can be readily visualized in Figure 9 where average boiler efficiency is plotted against the moisture content of the wood fuel.

The wood boiler steam output for the monitoring period is compared with the total plant output in Figure 11. Increased plant reliability during the monitoring period is reflected with the wood boiler carrying an increasing percentage of the plant's total generated output. During the warmer months of June and July the wood boiler displaced 93.0% of the plant's output. The wood boiler is taken off line for ash raking an average of twice per day which accounts for steam generated by oil during this period.

The boiler thermal efficiency is based on heat input potential compared to thermal output for the unit. The following equation was used in determining wood boiler efficiency each month.

$$\text{Thermal Efficiency} = \frac{Q_s(H_s - H_f)}{Q_w \quad H_w}$$

Q_s = pounds of water evaporated each month

Q_w = pounds of bone dry wood delivered each month

H_s = Enthalpy of steam (BTU/lb)

H_f = Enthalpy of feedwater (BTU/lb)

H_w = Calorific Value of Wood (BTU/lb bone dry)

A graph showing the rate of steam production per pound of wood fed is presented in Figure 10 and has shown marked improvements during the monitoring period. The increase in boiler efficiency can be attributed to improvement in wood fuel quality and an increase in operator experience level in controlling the combustion process.

The boiler unit has operated well from a mechanical standpoint. The wood feed stoker screw was removed in June, 1984 and the kickplate section and two flyte sections were replaced because of wear. The stoker screw is one area of the boiler which requires on-going maintenance, as sand and contaminants present in the wood residue will cause excessive wear of the stoker screw. A spare screw has been purchased and is located on site as a stand-by for change out when the screw in service is not capable of conveying full wood feed rates because of worn flytes and kickplates. Testing is ongoing to determine the best metal hardsurfacing material available to maximize the service life of the stoker screw.

A regular maintenance program has been developed at the plant whereby each piece of equipment is catalogued and a preventative maintenance checklist and lubrication guide is provided for the plant maintenance personnel. The boiler proper is scheduled for maintenance work every twelve months for gas and water side inspection and cleaning. The first planned shutdown was completed in August 1984 and the boiler was taken off line for a total of 10 days The boiler required some refractory work in the furnace area during the shutdown and a noticeable build-up of kreosote was found in the cold end section of the Tubular air heater unit.

4.3.2. Boiler Environmental Performance

Integral in the original design of the Babcock and Wilcox Towerpak boiler, was consideration of the plant's environmental performance. The boiler, when operating at peak load, was designed to meet or better the particulate emissions limits pursuant to the New Brunswick Clean Air Regulations.

The regulations state that the emission of particulate material from a stationary source shall not exceed 500 milligrams per standard cubic meter of dry flue gas corrected to standard conditions and 12% carbon dioxide concentration.

Controlling particulate emissions from the boiler is accomplished by mechanical dust arrestors installed in the discharging flue gas stream and by maintaining proper operating procedures for the unit. The wood-fired boiler is equipped with an Air Corrections Ltd. multi-cyclone collector which is designed to remove particulate matter in the existing flue gas stream with an overall efficiency of 90% under full boiler load conditions.

Following proper operating procedures by the plant operators is critical in minimizing particulate emissions from a biomass boiler. The operator must carefully monitor furnace draft levels as an excessive furnace draft can lift fuel from the furnace bed and into suspension. This results in carryover of char and flyash with the flue gas. The control of excess oxygen levels at the boiler outlet duct is important in optimizing thermal efficiency; however, operating with too low an excess oxygen level can have a starving effect on the fuel bed which causes smoldering and high smoke levels to occur. To assist the operator in adjusting furnace combustion air requirements, an

opacity meter with an alarm was installed to monitor the smoke density of the flue gas leaving the dust collector. The operator adjusts excess oxygen to around 3% and opacity at 40%. The opacity alarm is activated if the level reaches or exceeds 60%.

A special environmental consultant completed performance testing of the new boiler in September 1984,and the results are presented in Table 3. The boiler averaged a steaming rate of 33 000 pph during the three tests conducted with an average particulate emissions loading of 175 milligrams per standard cubic meter. The maximum loading allowed by the government regulation is 500 mg/scm.

TABLE 3
UNB WOOD-FIRED BOILER
ENVIRONMENTAL PERFORMANCE

TEST	STEAM LOAD POUNDS/HOUR	PARTICULATE EMISSIONS MG/SCM
1	33 000	169
2	29 500	168
3	32 500	188
AVG.	31 700	175

4.4 Ash Handling

As discussed in Section 2.7 of this report, ash is collected from five locations within the wood-fired boiler: the furnace grate, left and right hand generating banks sections, air heater hopper and the dust collector hopper. The type of ash generated varies with the location from which it is collected. The material on the furnace grate surface is sand and clinker based. The ash from the generating bank and air heater area has a high unburnt carbon or char content and the dust collector sample is mostly inert wood ash and dust. The ash is removed from the plant by a series of totally enclosed screw conveyors to one of two collection bins located behind the plant. A local contractor is responsible for removal of this ash for disposal at the city landfill site.

Early operating experience indicated that the volume of flyash generated was much higher than anticipated. The boiler, when operated over 30 000 pph, produces a large volume of flyash, of which as much as 50% is unburnt carbon. Testing conducted at the site indicated that operating without the generating bank rotary valves reduced the quantity of flyash produced by 30%. This gives the char leaving the boiler generating section a longer time in the gas stream and reduces the quantity of unburned carbon in the ash collected.

Depending on the boiler operating load, the furnace grate is manually raked two to three times per day. At a higher load, the larger volume of wood feed results in larger deposits of sand and rocks on the grate and the operators will clean ashes from this area every eight hours to prevent excessive build-up of ash and to improve operating efficiency. Under normal operation, flyash is collected continously from the air heater

and dust collector units. Testing has indicated that 70% of the flyash collected during this time originates from the dust collector and the remaining 30% comes from the air heater.

The quantity of unburned carbon leaving the plant with the ash is a major concern as this material has a tendency, when dumped at the landfill site, to continue burning. This has become a safety concern and to combat this problem water is added to the ash at the plant. The cost implications of char carryover can be seen in contractor charges which are based on a fixed price per bin disposed. A reduction in the unburned carbon content of flyash collected at the plant would result in lower volumes being collected and subsequently lower operating costs. Unburned wood fuel leaving with the combustion gases also resulted in lower efficiency for the boiler and has a measurable impact on the unit's profitability. For these reasons, some recovery options are being examined to reduce the carbon carryover.

5.0 PLANT PRODUCTION & SAVINGS

5.1 Production

The plant began operation in early March 1984 and by March 31 had produced 8.4 million pounds of steam. On April 1, the formal 6-month monitoring period was initiated.

Table 4 below shows the monthly steam production from wood fuel and total steam production for the plant for the monitoring period.

TABLE 4
STEAM PRODUCTION

Month	Steam From Wood Fuel (pounds)	Total Steam Production (pounds)
April	15 221 250	33 189 050
May	16 249 050	24 703 050
June	15 397 500	16 620 800
July	15 598 550	16 738 500
August*	10 963 801	16 516 950
September	17 518 050	19 141 250
Totals	90 678 201	126 909 600

This information is also plotted in a bar graph in Figure 11. It should be noted that a planned shutdown of approximately ten days duration was taken in August to carry out an inspection and correct some deficiencies. Consequently steam production from the wood fired boiler dropped to 66 percent of the total production for that month.

Total steam production from the wood fired unit for the six-month period ending September 30, 1984 was 90.9 million pounds which represented 71.4 percent of total steam production for the period. Total oil displacement is estimated at 644 000 Imp. gallons for the period.

5.2 Operating Savings

The calculation of operating savings as the result of adding the new wood-fired boiler must rely to some degree on estimates but the results are sufficiently accurate for the purpose intended.

The primary saving comes from displacement of higher priced fuel oil. The production of 90.7 million pounds of steam from the wood-fired boiler is equivalent to 590 000 gallons of fuel oil displaced and has an estimated value of $644 000.

The direct cost of steam produced by the wood-fired boiler for the same period is $256 000.

Incremental operating and maintenance costs include labor, materials, electricity, ash removal and supervision, and are estimated to be $110 000 for the six-month monitoring period.

As shown in Table 5, operating savings (before financing and administrative costs) are calculated to be $278 000 for the period which is equivalent to $3.18 per 1000 pounds of steam produced by the wood-fired boiler.

TABLE 5

ESTIMATED OPERATION SAVINGS

(Excluding Financial & Administration)

6 MONTHS ENDING SEPTEMBER 30/84

1.	Value of Fuel Oil Displaced	$644 000*
	Less:	
2.	Cost of Steam From Wood Boiler	$256 000
3.	Incremental Operating & Maintenance Costs (labor, materials & supervision)	$110 000*
4.	Subtotal	$366 000
5.	Operating Savings (1.-4.) (before financing & administrative costs)	$278 000

* Estimates Only

These operating savings are above the earlier estimate for the same 6-month period. As mentioned in Section 1, the projected annual production for the wood-fired boiler is 240 million pounds of steam and the experience for the first six months of commercial operation indicates that a direct operating saving of $640 000 per year will be achieved.

6.0 PROJECT COST ACCOUNTING

6.1 Cost/Benefit Analysis

A continuing overview of costs was maintained throughout the period with month end summaries prepared of committed and projected costs. this summary, up-dated each month, presented an accurate view of overall project costs and a guide to designers and management. Table 6 provides a breakdown of the total construction cost by each major item of the project.

6.2 Payback Period

The simple payback period is calculated by dividing the capital cost of the project by the annual savings.

$$\frac{\text{Capital Cost}}{\text{Annual Saving}} = \text{Payback period}$$

$$\frac{2\ 420\ 000^{*}}{640\ 000^{**}} = 3.78 \text{ years}$$

* includes cost of labour, materials, construction, engineering, project management and interest during construction.

** estimated annual saving (See Page 30)

TABLE 6

PLANT CONSTRUCTION COST*

Site Works	$ 420 500
Machinery & Equipment	446 000
Wood Boiler & Auxiliaries	1 384 000
Instrumentation & Controls	118 000
Piping & Valving	9 500**
Electrical Work	42 000
	2 420 000
Performance Monitoring and Information Transfer	35 000
Gross Project Cost	2 455 000
CREDA Grant	535 000
New Project Cost	$1 920 000

NOTE:

* - each category of cost includes construction labor and materials as well as engineering, project management and interest during construction charges.

** - much of the piping was included in the "boiler" account.

7.0 CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

This project has successfully demonstrated the technical feasibility of using a wood-fired boiler to produce steam and displace fuel oil in a central heating plant application and, on the basis of the results of the 6-month monitoring program, that the project will achieve the projected cost savings.

7.2 Recommendations

It is recommended that this approach to energy savings be used at other institutions where detailed feasibility studies indicate that it is economic to do so and that particular attention be paid to the following elements:

(a) availability, price and long term stability of wood fuel supply

(b) quality and preparation of wood fuel

(c) selection of proven and reliable equipment

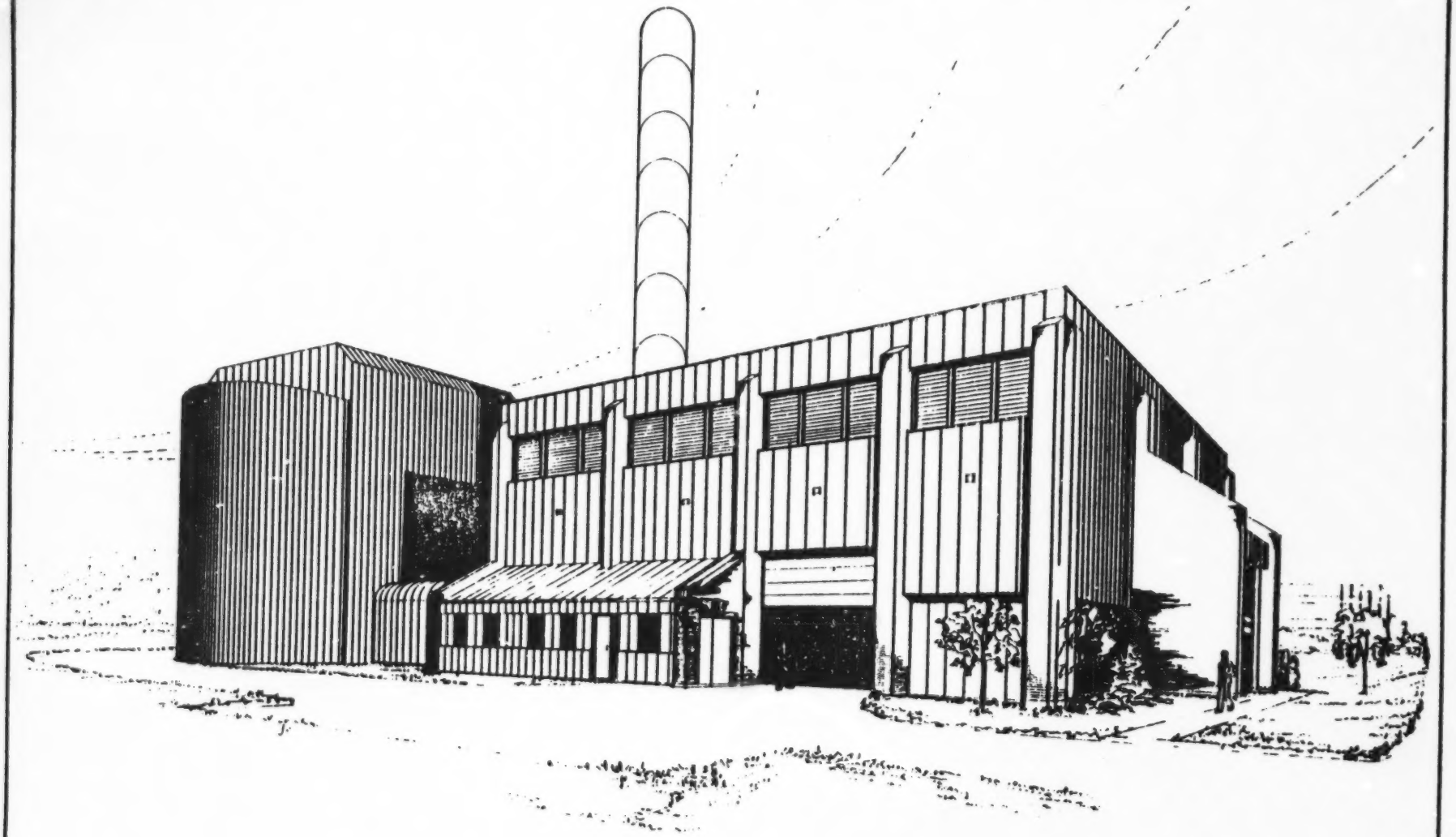
(d) training of operating staff

(e) plant cleanliness and environmental concerns

(f) plant safety

APPENDIX 1

FIGURES



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

Dwg. Title
PERSPECTIVE VIEW OF COMPLETED PLANT

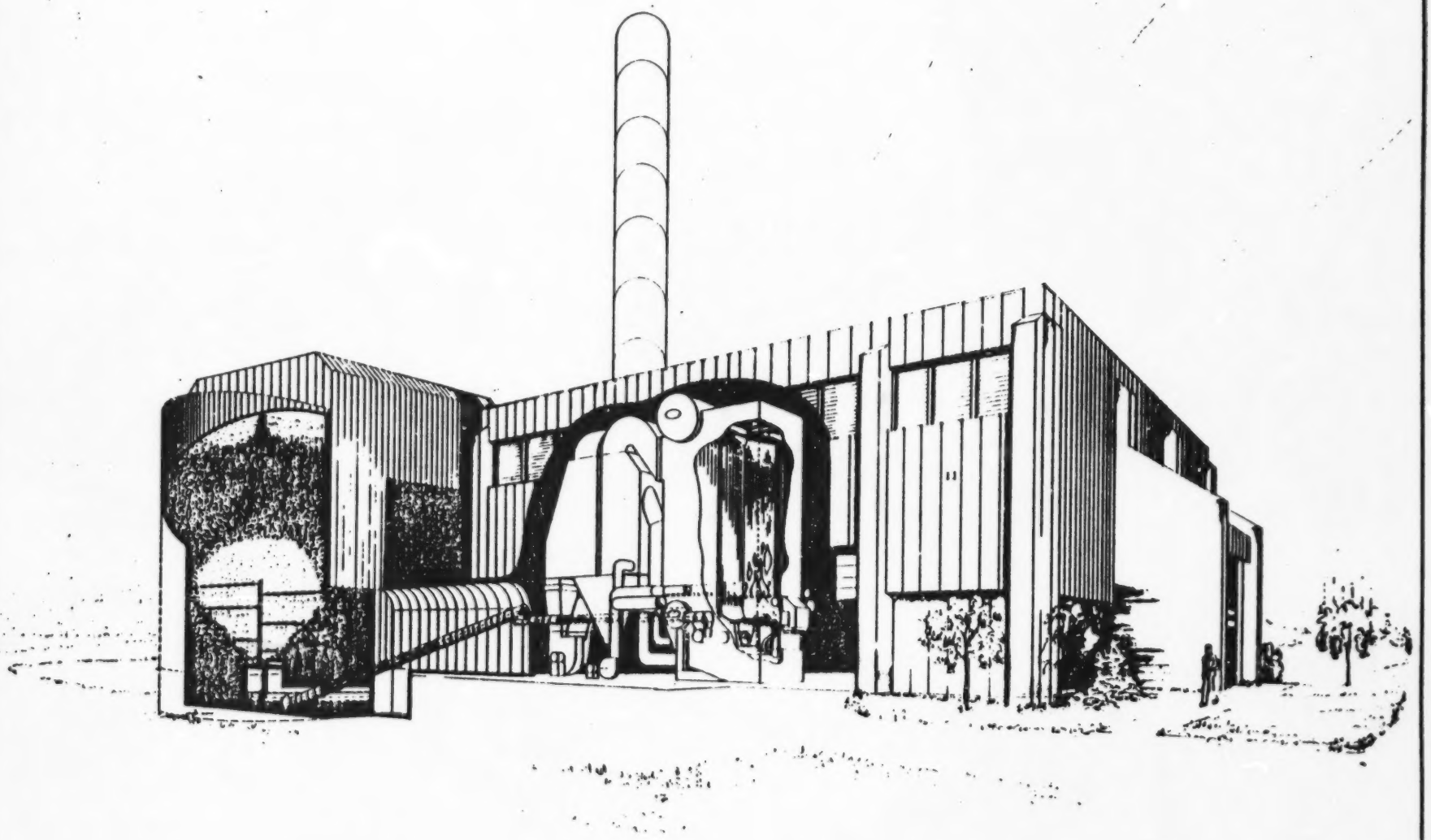
ADI Limited
Engineering Architecture Planning
Management Consulting Surveying
(506) 462-9000
1115 Regent Street
Fredericton NB

Project 1258-7

Dwg. FIGURE 1

Drn. By RAB | Scale — | Date 84/11

ADI107 84 04



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

Dwg. Title
CUTAWAY VIEW OF COMPLETED PLANT

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Management Consulting Surveying
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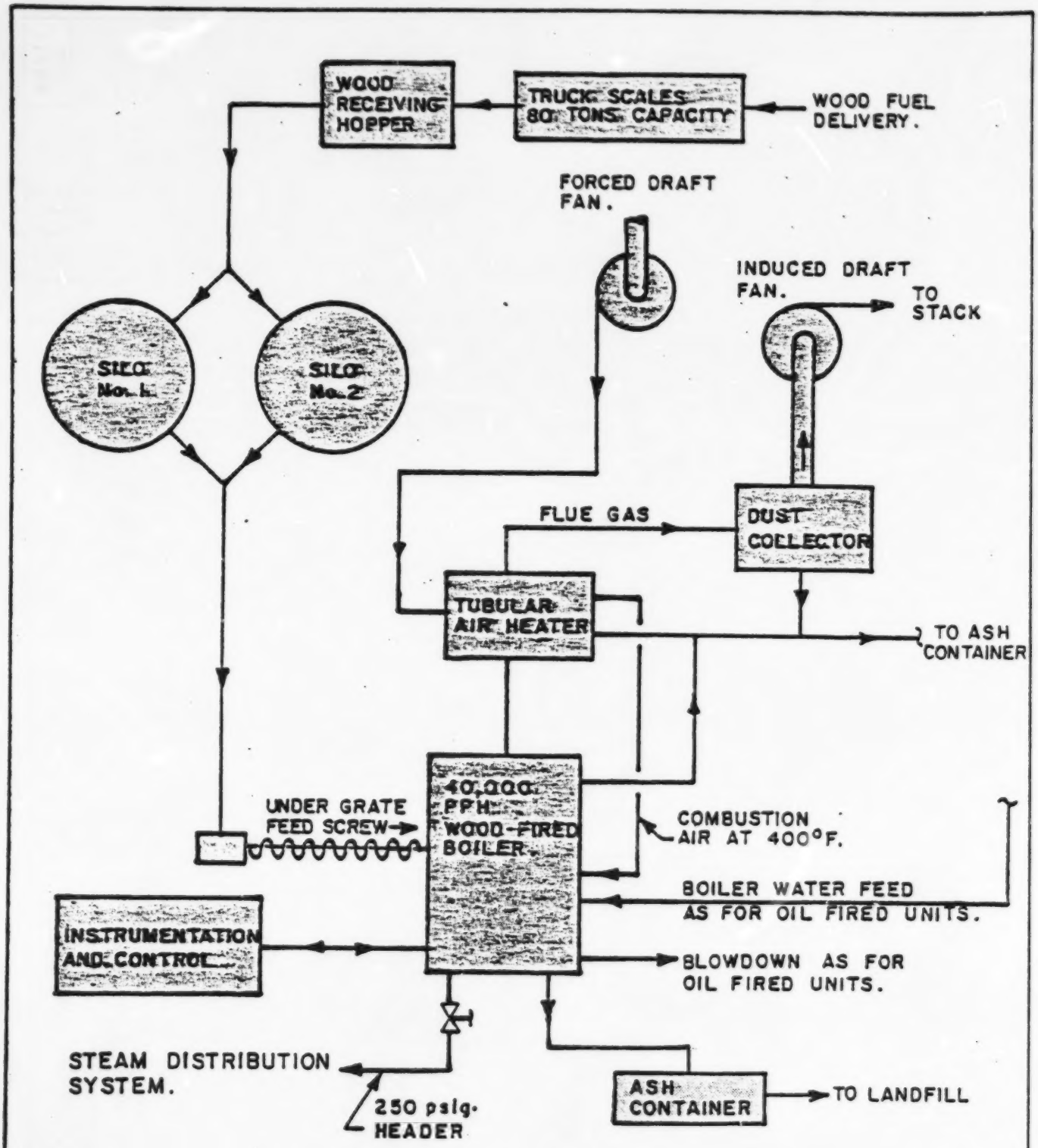
Fredericton NB

Project 1258-7

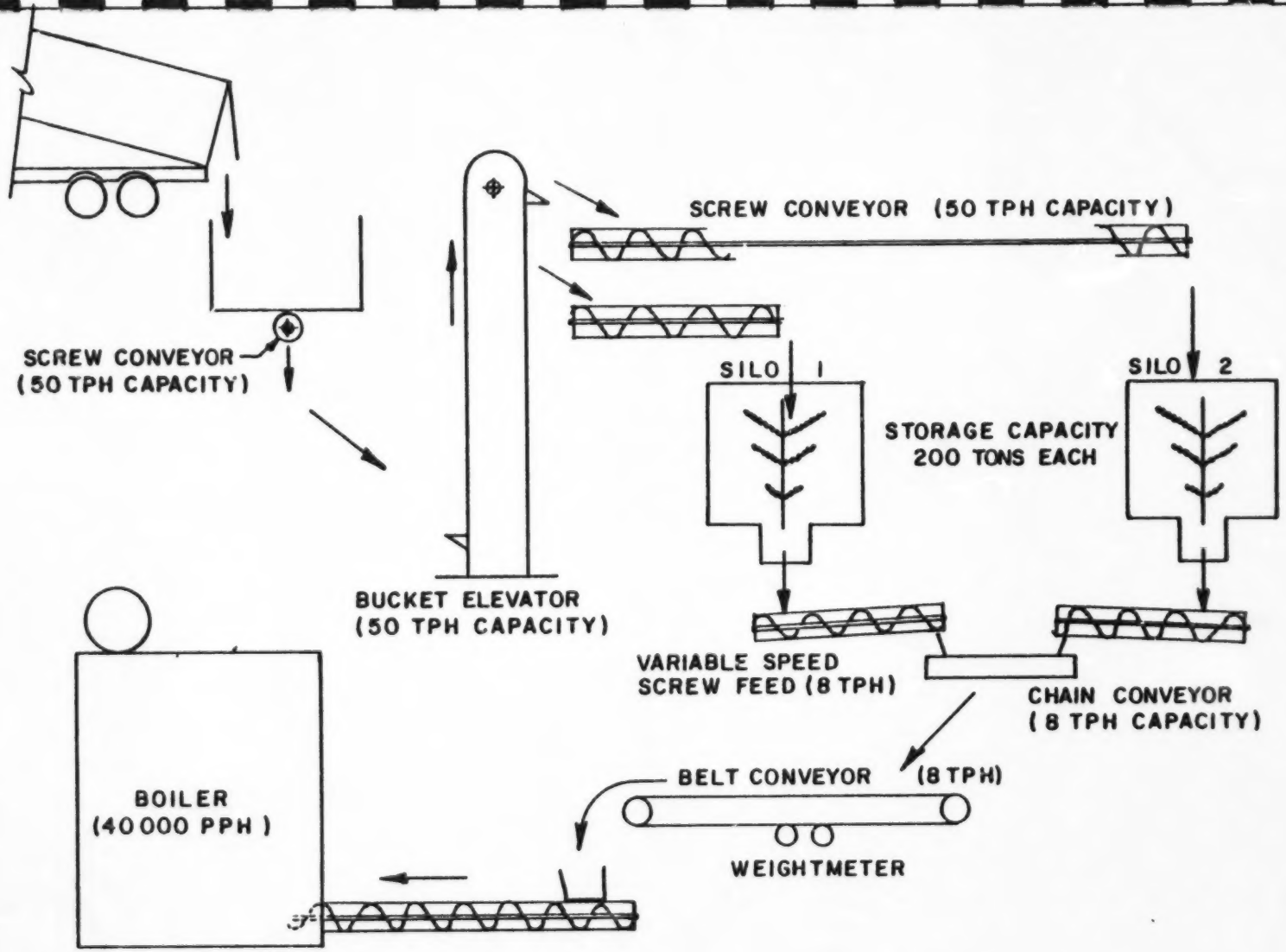
Dwg. FIGURE 2

Drn. By	Scale	Date
RJS	—	84/11

ADI 1107 84 04

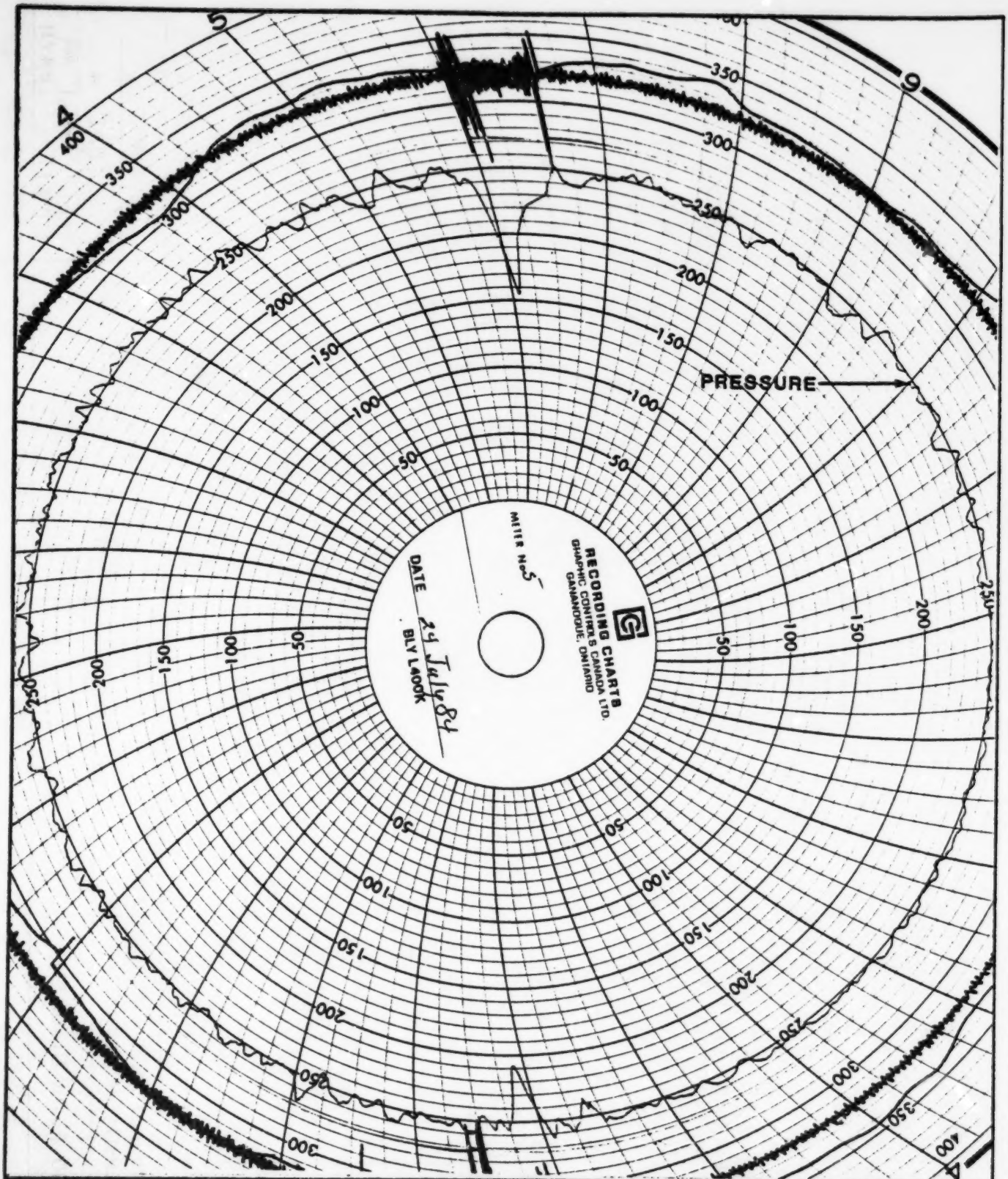


Project Title: ADDITION OF WOOD FIRED BOILER UNIVERSITY OF NEW BRUNSWICK	ADI Limited Engineering, Architecture, Planning, Management Consulting, Surveying (506) 452-9000 1115 Regent Street Fredericton, NB	Project: 1258-7	
Dwg. Title: GENERAL FLOW DIAGRAM		Dwg.: FIGURE 3	
		Drn by: R.C.P.	Scale: — Date: 84/11



Project Title: ADDITION OF WOOD FIRED BOILER UNIVERSITY OF NEW BRUNSWICK	ADI Limited Engineering Architecture Planning Management Consulting Surveying (506) 452-9000 1115 Regent Street Fredericton NB	Project: 1258-7	
Dwg. Title: WOOD FLOW DIAGRAM		Dwg.: FIGURE 4	
		Drn. By: RAS	Scale: —
			Date: 84/11

ADI 107.84.04



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

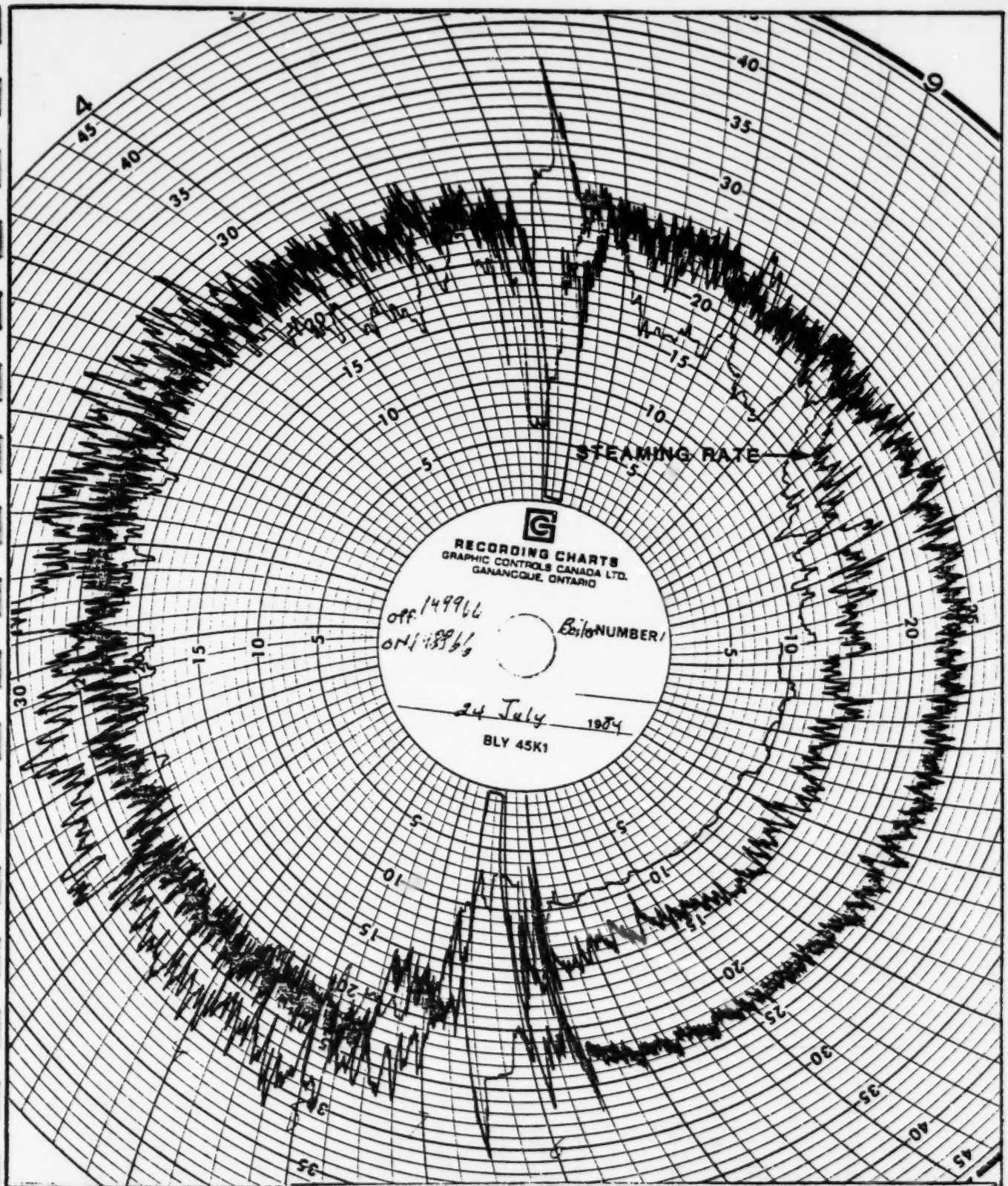
Dwg. Title
MAIN PLANT
STEAM PRESSURE CHART JULY 24/84
(WOOD BOILER CONTROLLING LOAD)

ADI Limited
Engineering, Architecture, Planning,
Management Consulting, Surveying
(506) 452-9000
1715 Regent Street
Fredericton, NB

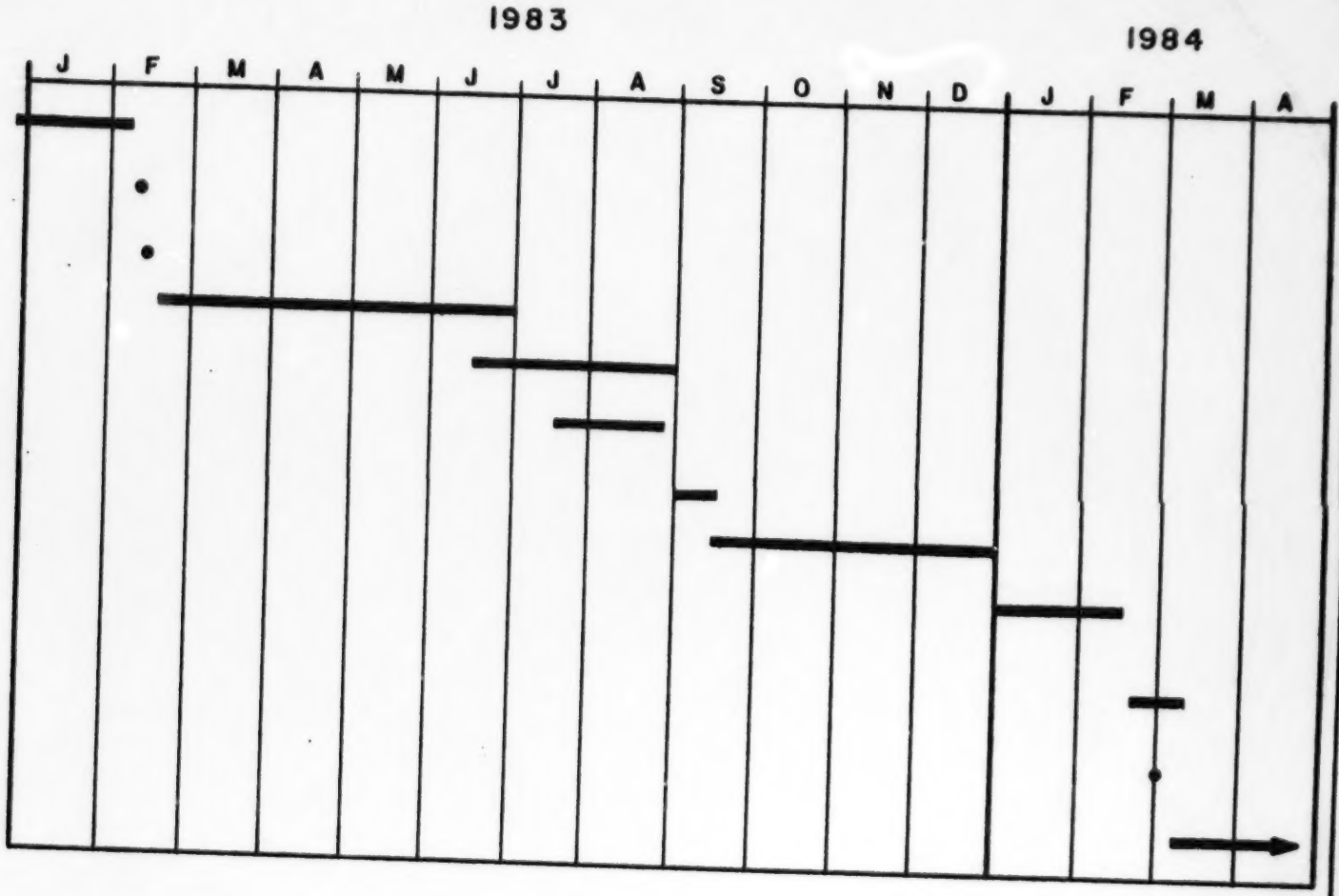
Project
1258-7

Dwg.
FIGURE 5

Drn. By RJD | Scale — | Date 84/11



Project Title: ADDITION OF WOOD FIRED BOILER UNIVERSITY OF NEW BRUNSWICK	ADI Limited Engineering, Architecture, Planning, Management Consulting, Surveying. 1(506) 452-9000 1115 Regent Street Fredericton, NB	Project: 1258-7	
Dwg. Title: WOOD BOILER CONTROL CHART INDICATING RATE FOR JULY 24/84		Dwg.: FIGURE 6	
		Dwn.	Scale: —
			Date: 84/11



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

Dwg. Title
PROJECT SCHEDULE

ADI Limited
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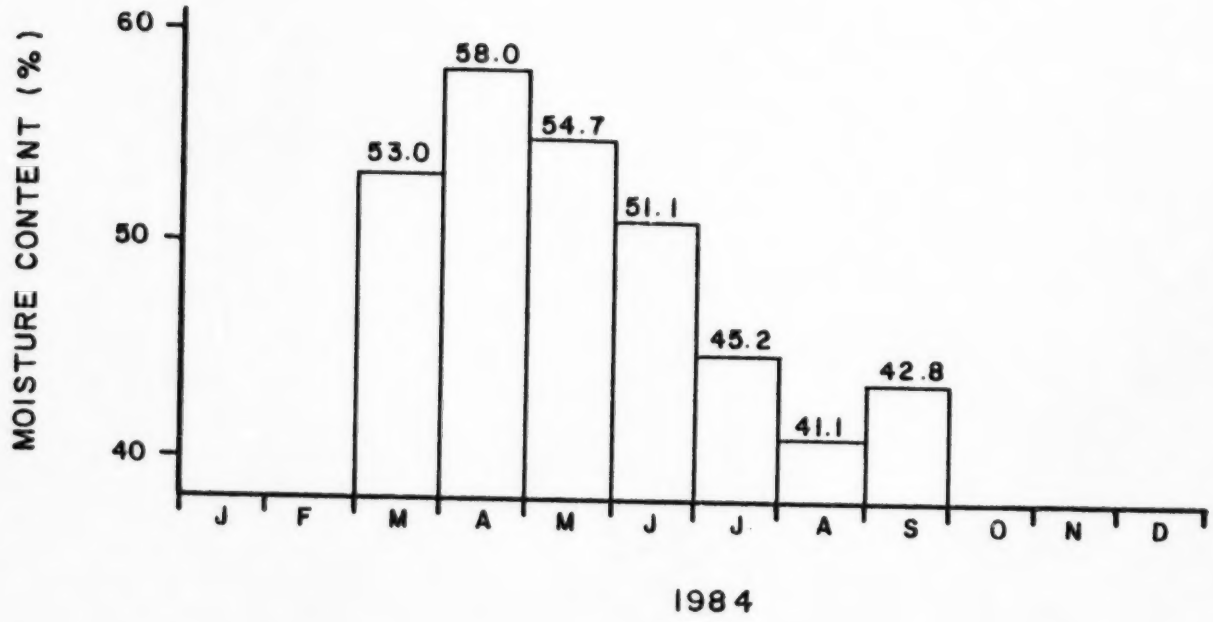
Fredericton NB

Project 1258-7

Dwg. FIGURE 7

Des. By	Scale	Date
KW	—	84/11

ADI107 84 04



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

Dwg. Title
AVERAGE MOISTURE CONTENT OF WOOD FUEL

ADI Limited
Engineering. Architecture. Planning.
Management Consulting. Surveying
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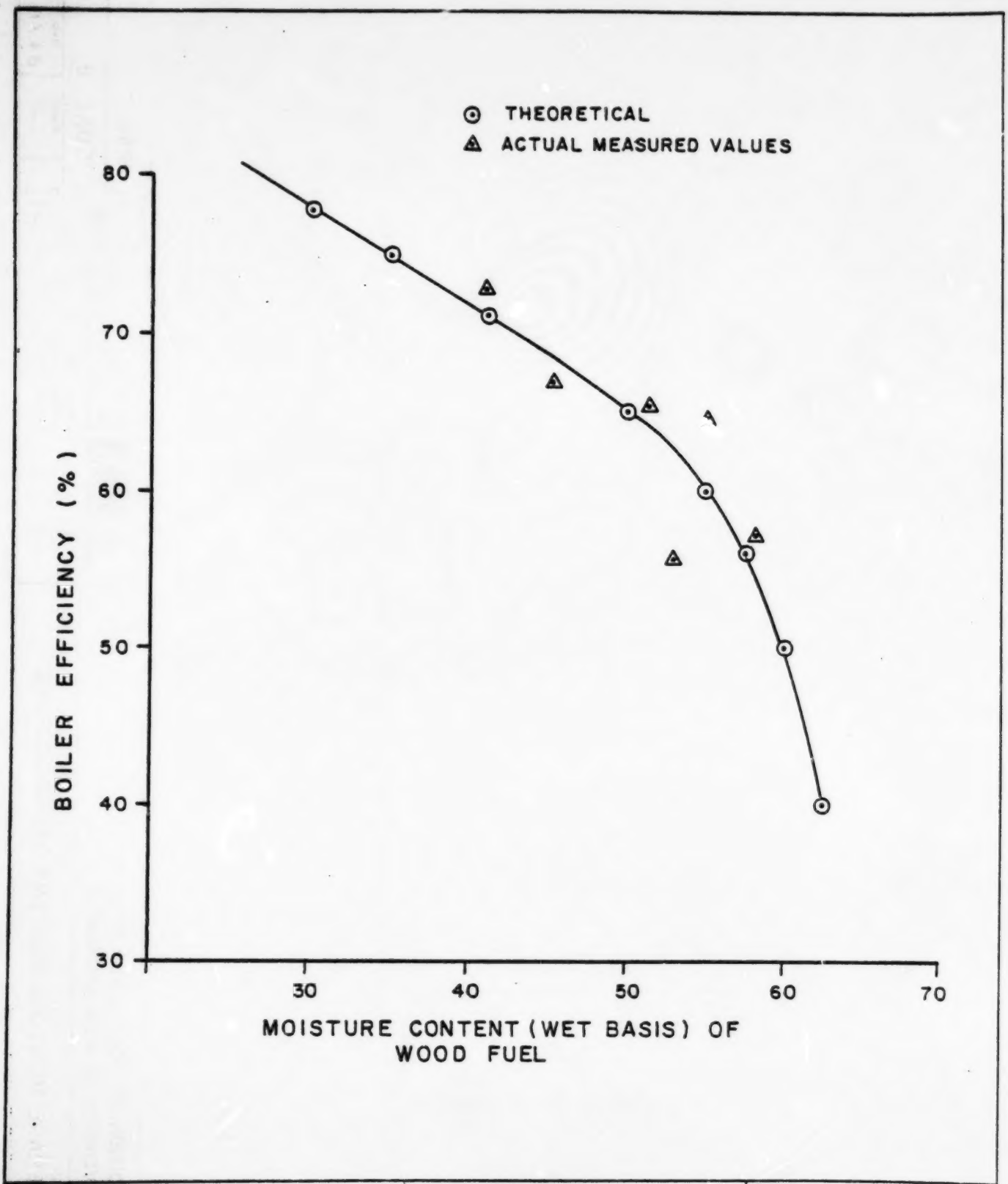
1115 Regent Street
Fredericton NB

Project 1258-7

Dwg. FIGURE 8

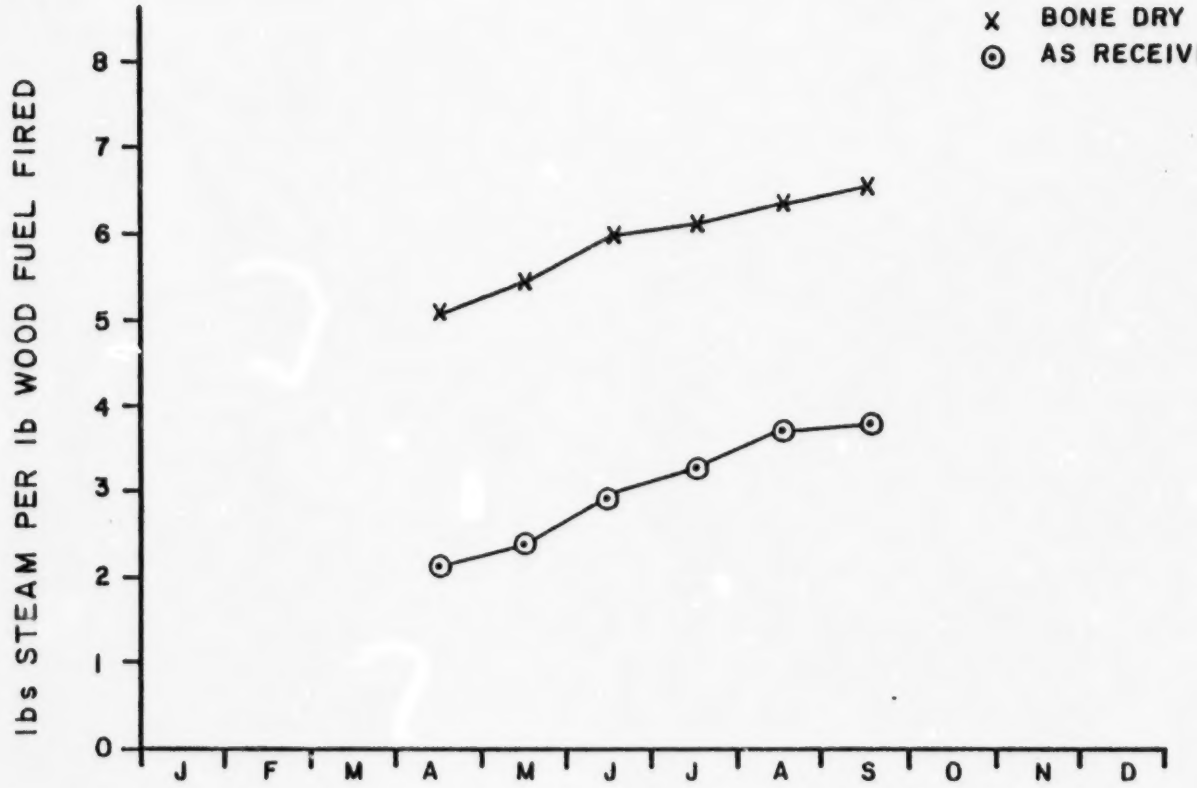
Drn. By RLS | Scale — | Date 84/11

APR1707 84 04



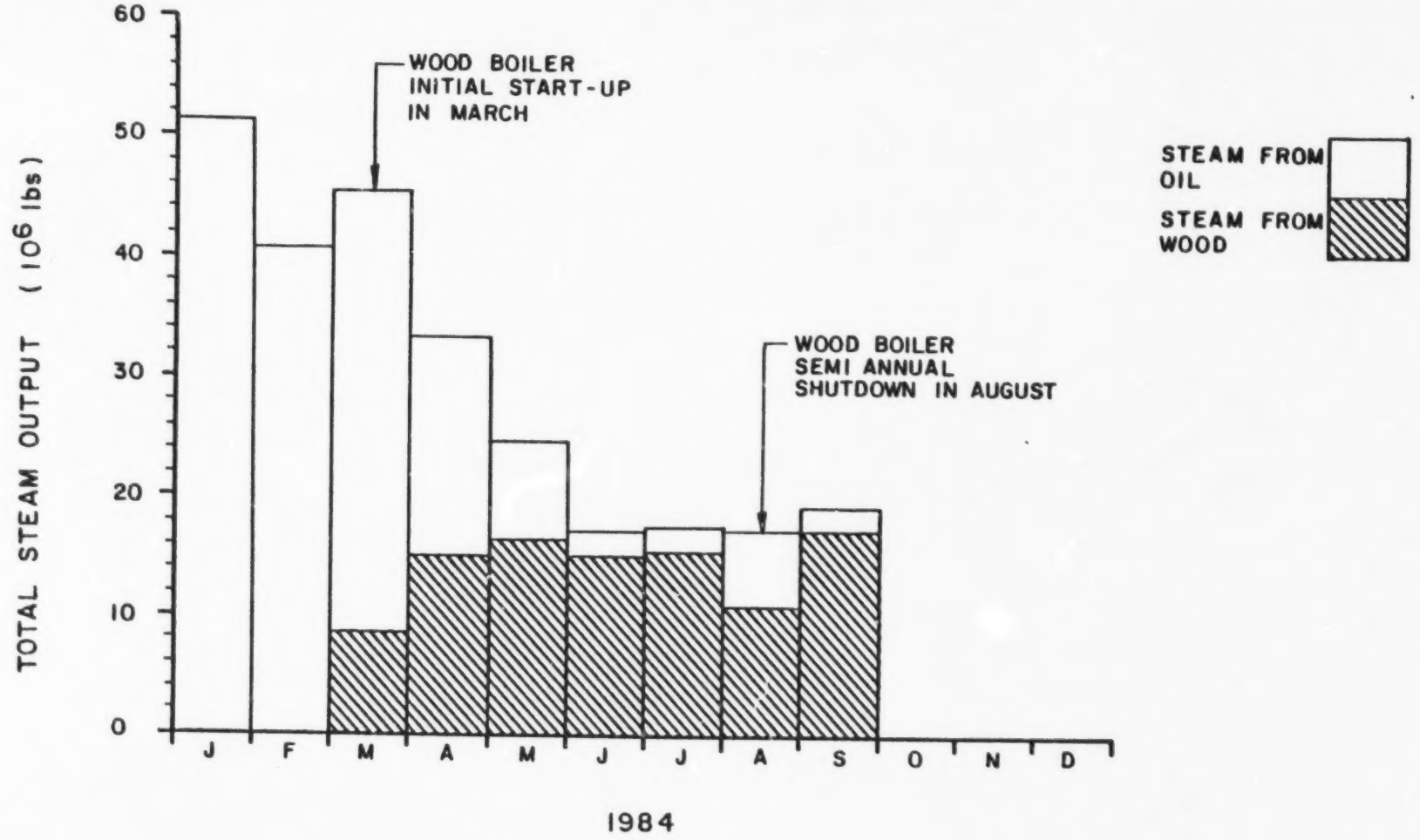
Project Title: ADDITION OF WOOD FIRED BOILER UNIVERSITY OF NEW BRUNSWICK	ADI Limited Engineering, Architecture, Planning, Management Consulting, Surveying (506) 452-9000 1115 Regent Street Fredericton, NB	Project: 1258-7	
Dwg. Title: AVG. BOILER EFFICIENCY WITH VARYING WOOD FUEL MOISTURE CONTENTS		Dwg.: FIGURE 9	
		Drn. By: RGNB	Scale: — Date: 84/11

ADI105 84 04



Project Title: ADDITION OF WOOD FIRED BOILER UNIVERSITY OF NEW BRUNSWICK	ADI Limited Engineering Architecture Planning Management Consulting Surveying (506) 452-9000 1115 Regent Street Fredericton NB	Project: 1258-7	
Dwg. Title: RATE OF STEAM PRODUCTION (lbs STEAM PER lb OF WOOD FUEL FIRED)		Dwg.: FIGURE 10	
		Drn. By: RJW	Scale: — / Date: 84/11

ADI1257 84 04



Project Title
ADDITION OF WOOD FIRED BOILER
UNIVERSITY OF NEW BRUNSWICK

Dwg. Title
PLANT STEAM PRODUCTION

ADI Limited
Engineering Architecture Planning
Management Consulting Surveying
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1115 Regent Street
Fredericton NB

Project 1258-7

Dwg. FIGURE 11

Drn. By	Scale	Date
RdS	—	84/11

AD1107 84 04